Development of Advanced High-Performance Electrolytes for Lithium-Ion Batteries Used in Vehicle Applications

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Project ID: ES292

June 7, 2016 AMR Review

soulbrain MI

Overview

Timeline

Start Date: January 7, 2016
End Date: January 7, 2018
Percent Complete: 15%

Budget

Total Project Funding:
- USABC: $1.079 million
- soulbrain MI: $1.079 million

Funding for FY 2016: $1.033 million

Barriers

Performance: Much higher energy densities are needed to meet both volume and weight targets.

Abuse Tolerance: Many Li batteries are not intrinsically tolerant to abusive conditions such as short circuits, over charge, over discharge, crush impacts, or exposure to fire and other high-temperature environments

Cost: The current cost of Li-based batteries is approximately $800 - $1,000/kWh, a factor of about three times too high on a kWh basis

Partners

USABC – Program Management
soulbrain Co. Ltd – Technology Transfer
Iontensity – Cell Assembly and Testing

Relevance and Project Objectives

- Overall Objective: Development of an electrolyte that addresses the shortcomings of current formulations and results in improved performance (>4.5V), increased abuse tolerance (overcharge), as well as lower cell and system cost for electric vehicles (<$11/kg for electrolyte)

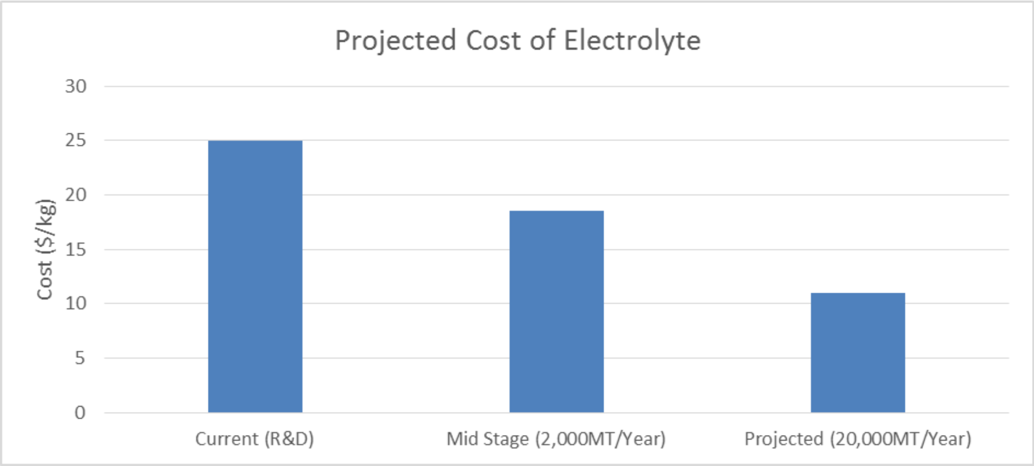
- Objectives (January 2016-March 2016): baseline testing at HE-NMC half cells, begin cost reduction of developmental additives

Milestones

	2016 Q1	2016 Q2	2016 Q3	2016 Q4	2017 Q1	2017 Q2	2017 Q3	2017 Q4
Characterize HE-NMC Baseline								
Characterize LMNO Baseline								
Evaluate HV Electrolyte in Small Format Pouch Cells								
Evaluate HV Electrolyte in Large Format Pouch Cells								
Cost Reduction of Developed Materials								

Approach/Strategy

- Scale up electrolyte being used in small format cells at high voltage (>4.3V) for the large format vehicle market.
- soulbrain Co. LTD., (parent company) in South Korea has been developing electrolytes for 20 years.
- With this extensive knowledge being passed to the US facility, the market readiness of new electrolyte formulations and their high-volume production can be developed quickly.
- soulbrain MI has an established customer base at commercial scale ready for production.
- soulbrain specializes in optimization of formulas that can move to full production rapidly.



Approaches to Improve High-Voltage Materials

Many high-voltage electrode materials are available from major active materials suppliers, but high voltage cells have not been commercialized due to poor cell performance, mainly due to lack of adequate electrolyte formulations.

Material suppliers are working on several approaches to improve long-term performance of high-voltage materials:

- Doping to stabilize crystal structure (Al, Mg, Ti, etc.)
- Surface coatings with metal oxides, fluorides and phosphates (Al_2O_3, ZnO_2, AlF_3, MgF_2, $LaPO_4$, etc)
- ALD coatings

Other considerations:

- Reduction of conductive additive surface area will result in less electrolyte oxidation at high voltages
- Separator oxidation at high voltage and high temperature can become a non-issue by using ceramic coated separators

It is generally agreed that major improvements are expected to come the in-situ formation of surface films by reactions with electrolyte additives and solvents.

Cathodes for High-Voltage Electrolyte Testing

LNMO has 4.7V plateau!

NMC can go beyond 4.3V but requires the correct electrolyte

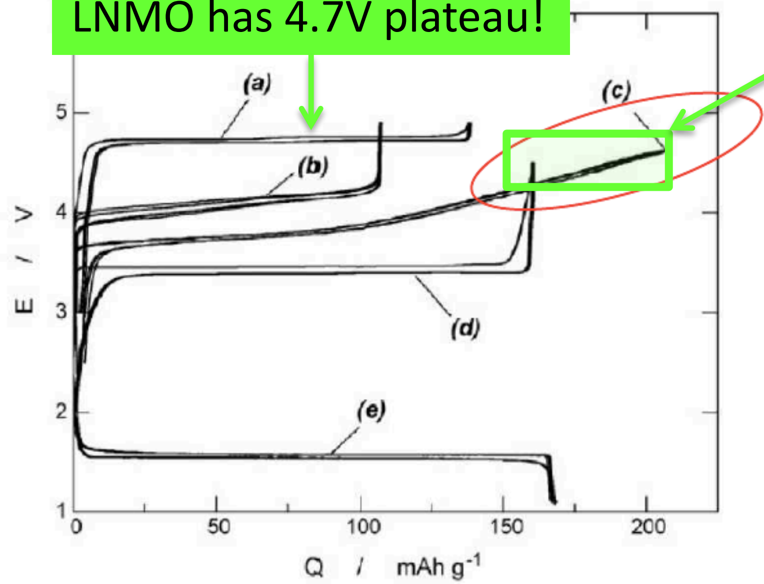


Figure 26.13. Potential versus specific capacity for (a) $LiNi_{0.5}Mn_{1.5}O_4$ spinel, (b) a $LiMn_2O_4$ spinel based lithium aluminum manganese oxide (LAMO, with Al and excess Li), (c) $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$ (NMC 111), (d) $LiFePO_4$, and (e) $Li[Li_{1/3}Ti_{5/3}]O_4$ spinel (a potential negative electrode material).[31]

From: Handbook of Batteries, 4th Edition, McGraw Hill, 2010, originally from T. Ohzuku

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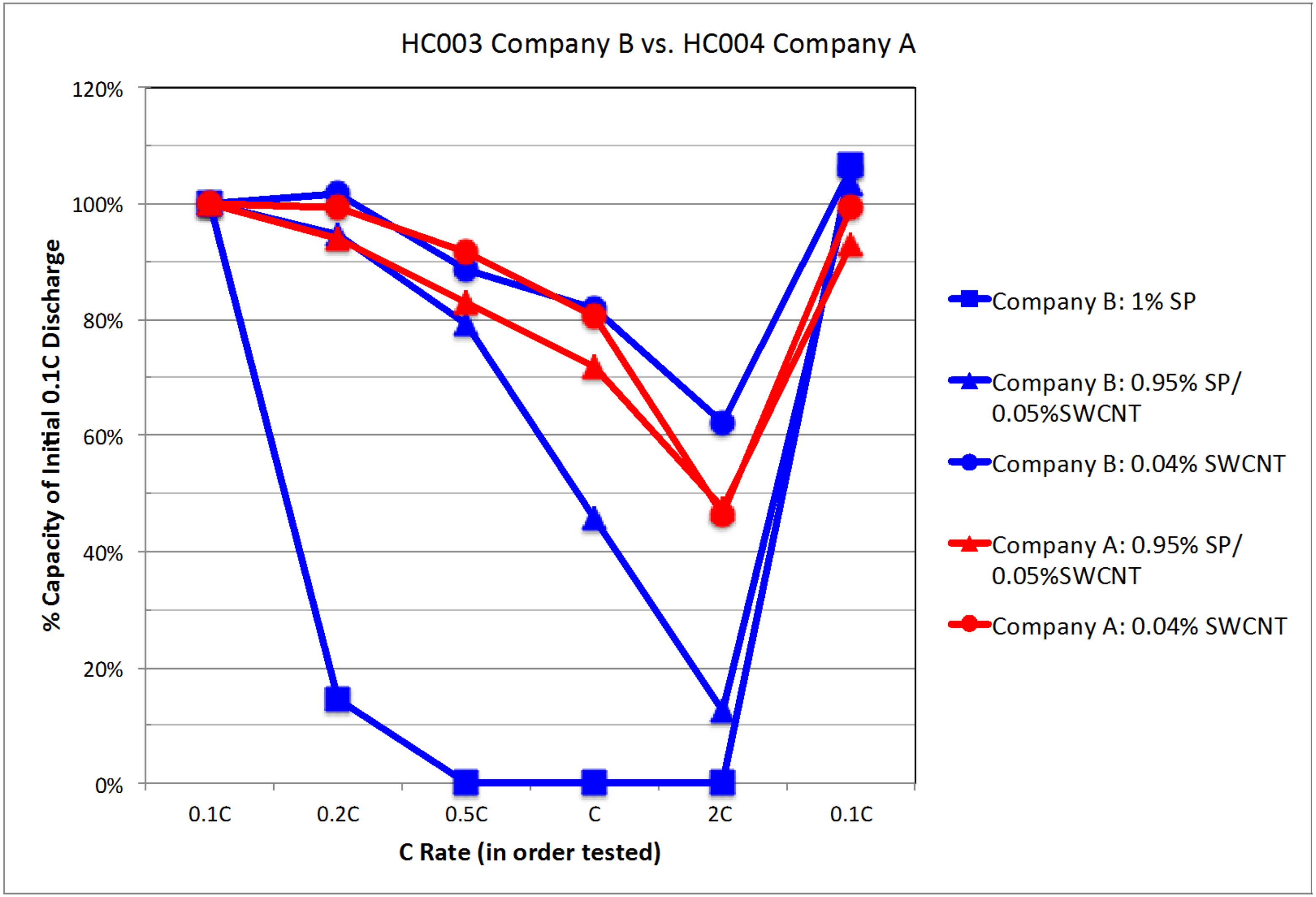
- We will use 3 vendors of NMC for up to 4.5V:
- We will use 2 vendors for $LiNi_{0.5}Mn_{1.5}O_4$ for use up to 5V:

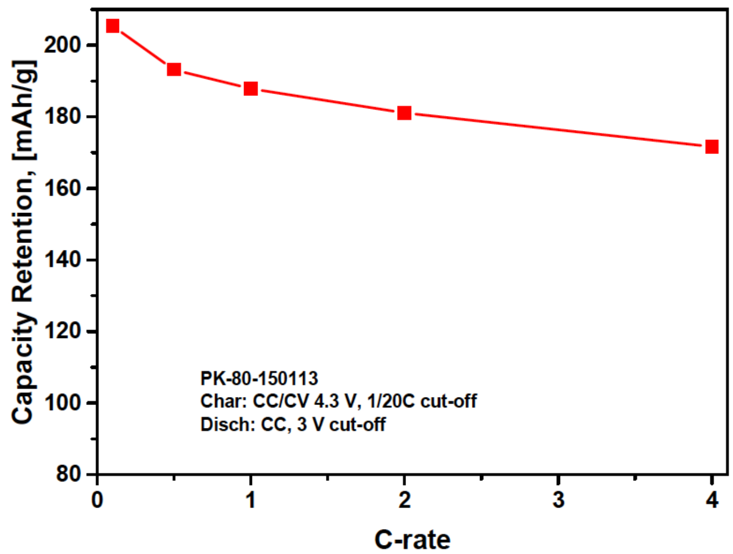
2016 Accomplishments

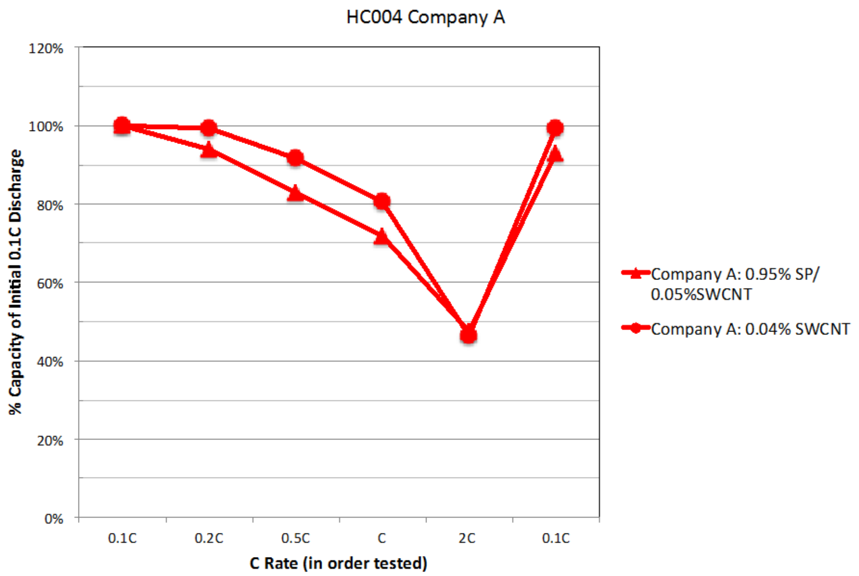
- Several electrolyte formulations have been prepared and HE-NMC electrode formulations coated
- Half-cells assembled and under testing is underway
  - Formation, Rate Testing, Cyclic Voltammetry
  - Cycle Life Testing
  - DSC
- Timing:
  - Program is on track with its overall schedule

SWCNT vs. Super P Rate Testing



NMC 811 (Company A) – Rate Comparison 4% vs. 0.04% conductive additive





- <u>Company A Test Cell</u>
- 92% Active
- 4% Denka Black
- 4% Kureha PVDF

Important to reduce total surface area of conductive additive in electrodes using SWCNT

- <u>Our Test Data</u>
- Two formulations with SWCNT:
  - 0.95% Super P / 0.05% SWCNT
  - 0.04% SWCNT
- Good rate capability for 98.46% Active and only 0.04% conductive additive

Response to Previous Years Reviewers' Comments

- The program began in 2016, no reviews from last year.

Collaboration and Coordination

- USABC
  - Program Management
- soulbrain Co. Ltd. (parent company)
  - Oversight, Technology Transfer
- Iontensity
  - Cell Assembly and Testing

Remaining Challenges and Barriers

- A prime challenge for high voltage stability is the cathode chemistry. Production of high voltage cathode materials (both HE-NMC and LMNO) are still at the R&D scale.
- Optimization of the electrolyte will help stabilize the cathode-electrolyte interface and hence the cell performance. The final solvent/salt/additive mixture will depend heavily on the choice of cathode

Proposed Future Work

- The cyclic voltammetry helped narrow down the cathode/conductive additive mixture for future tests
- All of the formulations need to be tested to begin optimization of the electrolyte for the HE-NMC at high voltages
  - Half-cell testing in progress
  - Full-cell testing scheduled for 2016 Q2
- LMNO testing (half- and full-cell) is scheduled for 2016 Q2
- Electrolyte formulations for both cathode systems will begin to be optimized once data is collected - 2016 Q3 (begin)